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MULTIMOBIL 5C

SP

Function Description

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Multimobil 5C

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Circuit Description

Version 5.0

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1 Circuit Description

1.1 Master card D915

1.1.1 Power Supply

The +15, 0V, -15V and +5V, 0V voltages are obtained from the SMPS1 through the Connector X15.
The reference voltage for the Microcontroller (J31) is 5V and it is generated by R119, C85, and J30.

1.1.2 RESET Generation

The $\overline{RST}$ signal is generated by IC J40 (MAX700: power supply monitor with reset) at power ON. The switch SW2 also allows for manual reset of the system.
On actuating SW2 ON, reset is generated by J40, which is applied to $\overline{RST}$ of J31.

1.1.3 Crystal Operation

The 12 MHz Quartz crystal forms a Pierce Oscillator along with the two capacitors C93 and C95. The output of the oscillator is a 12MHz sinusoidal wave, which is applied to XTAL1 and XTAL2 inputs of J31 for providing timings for internal operations of the microcontroller.

1.1.4 Microcontroller

The micro controller J31 outputs demultiplexed lower order address bus and the data bus on port 'P0' and higher order address bus on port 'P2'.
The control signal $\overline{RD}$, $\overline{WR}$ along with A8-A15 are provided to J28 (GAL) to generate the chip select signals for accessing various peripherals.
The status signal $\overline{PSEN}$ is used for reading external program stored in EPROM J32.
The $\overline{EA}$ 'LOW' allows accessing the external program memory.
Different signals for controlling various operations of the entire system are provided by the Micro controller on its ports P1, P3, P4, and P5.
The analog inputs AN0 - AN6 are used for monitoring analog signals.
The pins TxD and RxD are used for serial communication between the processor and the external device such as a Computer for servicing.
The Service switch ST provided at pin P4.5 is used for operating the Unit in the service mode.

1.1.5 Octal Latch

The multiplexed address and the data bus is separated by the octal latch J27.
At the active ALE signal, the lower order address (A0-A7) is latched.

1.1.6 GAL

Since Memory mapping technique is used, the chip select signals for various peripheral devices are generated by the Gated Array Logic IC J28. The inputs are the address lines (A8 - A15), and the control signals $\overline{RD}$ and $\overline{WR}$. The output lines are $\overline{CS1}$ to $\overline{CS8}$.

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These output chip select lines are generated on the basis of the logic implemented in the program stored in the GAL.

1.1.7 EPROM

The entire program is stored in a single EPROM J32.

1.1.8 NVRAM

The 2 Kbytes NVRAM stores the variables during the operation of the unit.
A0 - A10 and D0 - D7 are the address and the data lines provided to the RAM. The first 2 Kbytes of entire memory space 0000H to 07FFH is used as RAM.

1.1.9 Keyboard

The keys are accepted through X12 from D507.
The keys kV+, kV -, mAS+, mAS-, ON, OFF are accepted on the data bus through J38 and J37 at the address 9000H.

1.1.10 Display

The data bus, the control signal $\overline{WR}$ and the chip select signal $\overline{CS2}$ are provided to the Display Driver J24 on D507 through X1. Writing the control word and the string of 8 byte data at the addresses 8000H and 8800H respectively displays the kV and mAS values and lights up function related LED's on D915.

1.1.11 Serial Communication

TXD, RxD are provided to the serial communication port of D915. Various activities of the unit can be controlled by an external device such as a PC. The serial port is meant for testing and service purposes.

1.1.12 kVsoll and mAsoll

The kVsoll and mAsoll values are generated by Dual Digital to Analog Converter J17 and the Op-amp J13 acting as I - V converter.
The microcontroller J31 outputs the digital values of kVsoll and mAsoll on the data bus at address A000H ($\overline{CS3}$) and A100H ($\overline{CS4}$) respectively. The reference current for DAC is adjusted by means of presets P6 and P7.
The kVsoll and mAsoll are fed back to the AN3 and AN4 pins of J31 for ensuring their proper values. These soll values are also used for regulation of kV and mA.
The kV soll ratio is 1 V = 30 kV and the mAsoll ratio is 1 V = 20 mA.

1.1.13 Line voltage monitoring

The actual mains Line voltage stepped down & converted to DC and through differential amplifier it is fed to V-Bat input point of ADC. This DC voltage is monitored every 5 second and line voltage is displayed during selection of hand held Exposure switch for radiography. If the measured Line voltage is less than 200 volts , microcontroller sends one signal to switch ON the LN contactor which will support extra voltage through auto transformer for 2.5 KW power generation. This switching ON/OFF of LN contactor is done every 5 sec. In preparation and exposure mode contactor retains its position. After 5 second of each termination of radiography Line voltage is monitored once again.

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1.1.14 kV Feedback

The actual kVp across the tube is stepped down and fed back to the Master card D915 at pins 1, of X8 as PKV with respect to the common terminal at pin 3.
PKV is passed through the voltage follower J5 and then fed to the Differential Amplifier formed by J5 to produce kVist used for kV regulation.
(KVist ratio is 1V= 20 kV)
As no differential configuration is used, NKV part is ignored by grounding it.
KVist is fed back to AN7of J31 for monitoring purpose.

1.1.15 IH Feedback

The filament current feedback is taken from the Interface card D506 through X11.1.
J7 provides a gain of 5 to Ih.
The AC filament current Iheiz is converted in DC value Ih by RMS-DC converter J6.
J9 provides an appropriate gain to Ih (that can be adjusted by preset P5) so that the ratio 1V = 1.13A holds true. Ih is fed back to J31 at AN2 for monitoring purpose and the same is used for Ih regulation

1.1.16 mA Feedback

The tube current (JR) is fed back at pin 5 of X8 on D915 & is applied to the Differential Amplifier formed by J4.
The output JR represents the actual tube current mAist which is fed back to J31 at AN1 through J9 for monitoring purpose. JR is also used for tube current regulation.

1.1.17kV Regulation

The kVsoll and kVist values are fed to the P-I controller formed by IC J10.
The difference between the kVist and kVsoll value is amplified to produce an appropriate error output, so as to compensate the error. The zener V12 limits the maximum output voltage of the error amplifier to 10V.
The error amplifier output is fed to PLL IC J3, which is used as voltage to frequency converter. The J10 output voltage produces an equivalent frequency REG at J3 output. For 10V, REG (the maximum firing frequency of the Main Inverter) is approx. 9.5 kHz. J3 is enabled by an active low INH2 signal provided by the microcontroller J31 at P4.1 through J23. During HT, J3 is enabled through INH2 and J3 results in a firing frequency of Main Inverter IGBT's, to result in actual kV in line with the required value.

1.1.18 Filament Regulation

Filament Regulation is divided into two parts:
1. Regulation without high voltage: The filament current Ih is regulated. CPU J31 feeds the required filament current value to the input of DAC.
2. The actual tube current JR is regulated. J31 outputs the required tube current on the input of DAC. Depending upon whether the regulation is pre H.T or post H.T either Ih or JR is selected through HEIZ signal from J31 (P4.4) and used for regulation together with the corresponding value from the DAC. The output of the error amplifier J10 is fed to PLL J2, which is configured as voltage to frequency converter. The PLL J2 is enabled through INH1 signal from J31 (P4.0) and generates a frequency in line with the output of error amplifier J10 to result in required filament current or the tube current.

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1.1.19 mAs Integration

The actual tube current is applied to the input of V-F converter J1. The transfer ratio (Frequency to Voltage) of J1 is adjusted by preset P1. The preset P2 is used for adjusting the offset at the output. The output frequency is selected by J8 only when the kVist reaches 90% of its final value.
The output of J8 is fed to J31 as timer 0 clock .The timer 0 inside J31 is configured as timer counter, which is preloaded with a count equivalent to mAs value. The incoming clock decrements the counter and on reaching '0', generates an interrupt to terminate the exposure.

1.1.20 Control of the Firing Pulse frequencies REG and CAL

REG is controlled by the signals INH2 and INH3 and it is enabled only when INH2=0 and INH3 =1 .
CAL is enabled only when INH1=0.

1.1.21 Generation of actual Firing Signals

1.1.21.1 Main Inverter Firing Frequency

The pulse duration of the actual firing signals of the Main Inverter is decided by the Monoshot Multivibrator J21 (IC 4538 Dual Monoshot Multivibrator) and R104, C66 and R105, C67.
The $\overline{RST}$ pin of J21 is normally high for its proper operation.
The outputs of J21 at pins 6 and 10 are out of phase. These signals are optically Isolated by J39 and J41 and fed to the Main Inverter Driver (D61) through X20.14 and X20.18.

1.1.21.2 Filament Regulator Firing Frequency

J18 is used to determine the pulse width of the actual firing signals of the Filament Regulator. The IC J20 ensures that the firing pulses to the Filament regulator are out of phase. These signals are inverted by J22 and fed to the Filament regulator firing circuit on D915 through X11.13 and X11.16.

CAL frequency is 0 Hz when error 03 is displayed and to Get CAL during Error 03 display, press DL_SERV key. This is done to overcome the problem of filament fusing off because even though open path in the filament circuit and filament is fired continuously for higher value. During this error cod E03 to analyse the fault and get CAL, press DL_SERV key.

1.1.22 Main Inverter Short Circuit Feedback SCM

During normal operation, the transistor V38 is ON and simultaneously the optocoupler is also ON. An active LOW error signal at X20.16 turns V39 and consequently J34 OFF. The J34 output becomes LOW to give the HIGH SCM (Main Inverter short circuit) signal. SCM is inverted by J22 and then it is fed back to the micro controller J31 for taking the corrective action.
The three signals SCM, KVM and JIM are used for disabling the Driving pulses of the Main Inverter. This is done by OR ing of these three signals by J14. At the occurrence of either of these three signals, $\overline{RST}$ goes LOW and its output is disabled.

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1.1.23 kV $_{max}$, mA $_{max}$ Feedback

1.1.23.1 KVM maximum kV

If the KVP value exceeds the reference value for 115kV at J12 (Comparator) its output generates the KVM signal. KVM is also fed back to J31 at P32 as Timer Zero Interrupt for initiating necessary corrective action like stopping the exposure instantaneously.

1.1.23.2 JIM maximum mA

An increase in Ih or JR than the reference values of 3.5A and 71 mA respectively generates JIM. JIM is fed as T1 interrupt to J31.

1.1.23.3 IH Maximum

This error is similar to JIM. This is monitored during preparation state and gives an interrupt if the filament current exceeds the maximum permissible current that is 3.6 Amperes.

1.2 Inverter assembly D61

1.2.1 IGBT's Inverter Assembly

Igbt Inverter Assembly houses IGBT's configured as bridge inverter, along with Inverter PCB D61 consisting of associated firing circuit, supply monitoring and short circuit sensing circuit.

1.2.2 Firing

With selection of single step exposure release switch for Radiography or Fluoroscopy foot switch and or Hand held Fluoro switch for x-ray generation, the microcontroller prepares for the exposure loading the kV and mA values required for the exposure into the DAC. This control circuit residing on the Master Card D915 then generates the firing pulses for the inverter which are available at the connector X6 of the inverter PCB through interface PCB D506.
On Inverter PCB D61, J1 along with resistors R13, R14 and capacitors C5, C6 form the pulse stretching circuit which stretch the Disp1 and Disp2 pulses to 64 μ Sec(the resonating time of the LC load) maintaining 180° phase shift. These phase shifted pulses drive the IGBT drivers which in turn generate the gate firing pulses for the IGBT's. Resistors R1, R4, R7, and R10 control the turn-on speed of the IGBT's. Resistors R2, R5, R8, and R11 control the turn-off speed of the IGBT's.

1.2.3 Inverter

U/V is the primary winding of the HT trafo which is in series with external resonating capacitor C4 and external inductor L2.
With Disp1 pulse the current path is completed through DC(+), 3-1 of IG1, A3, U/V, C4, L2, A2, 1-2 of IG2, DC(-). After 64 μ Sec the gate pulse is turned off and the IGBT's are turned off. The resonating capacitor C4 which is now charged to a voltage greater than the bank voltage discharges via the free-wheeling diodes in anti-parallel to the IGBT's.
With Disp2 pulse the current path is completed through DC(+), 3-1 of IG2, A2, L2, C4, U/V, A3, 1-2 of IG1, DC(-). After 64 μ Sec the gate pulse is turned off and the IGBT's are turned off. The resonating capacitor C4 which is again charged to a

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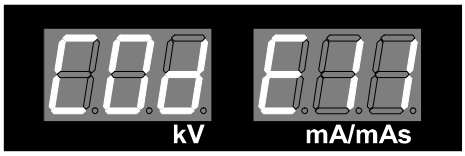
voltage greater than the bank voltage discharges via the free-wheeling diodes. The firing pulses have a maximum frequency of 9.2 kHz ± 0.3 kHz.
The presence of DC voltage is indicated by LED V1 on D61.

1.2.4 SCM

VCE of the IGBT's is monitored continuously by the IGBT drivers. In case of short in any IGBT's VCE will increase resulting in generating of active low signal on ERR pin of the driver. ERR pin is normally held high by a pull-up resistor in D506. The ERR pin can go low if the supply voltage falls below 13V instead of 15V. When this signal is sensed by the microcontroller, firing pulses are inhibited and Error Code 11 is displayed, and the IGBT's are turned off.



1.3 Interface PCB D506

1.3.1 ON/OFF Circuit

The mains voltage of 240 V ac appears across X1.1 and X1.2. The 15 Volts transformer T1 and regulator 7812 on the PCB provides the coil voltages for the On / Off relays K1 & K2. When Unit ON switch I is pressed, the circuit for Relay Coil K2 gets completed and causes the Relay K2 to energise. This causes the contact K2 to close and provide the ac voltage to the Main Transformer and other circuit points like SMPS (40 watts &120 watts) input and Contactor Coil connections. As the coil K2 energises the contact K2 (6,8) is established and hence the unit remains ON even if the "I" switch is released.
When the switch O is pressed the Relay K1 coil is energised and this causes the Normally Closed contact K1 (4,6) of relay K1 to open thereby opening the circuit connections for relay K2. The Unit thus is turned Off.

1.3.2 Line voltage measurement

Incoming Line voltage is stepped down to 15 volts when input is 230 AC. It is converted to DC & filtered using capacitor. This DC voltage is further stepped down using resistor divider network & potentiometer and given to differential amplifier for line voltage measurement through ADC on Master card D915.

1.3.3 Power Supply Distribution

The following connections are routed through the Interface PCB D506.

1. X1.9 & mains neutral	240 V ac for Contactor US Coil Connections
2. X1.4 & X1.6	240 V ac for SMPS (SMPS 1&2 ±15V;+5V) input Supply.
3. X1.4 & X1.7	240 V ac for CCU input Supply.
4. X1.5 & X1.2	240 V ac for Main Transformer
5. LN on D506 & mains neutral	240 V ac for Contactor LN Coil Connections
6. X1.8 & mains neutral	240 V ac for SMPS (D982 +24V, D985 +15V) input supply

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The contactor US and LN coils are energised only when corresponding signal from the Master Card D915 is obtained. This is achieved through opto-couplers J1 and J9 respectively. The contactor ON signal from the Master Card D915 intern drives optocoupler J1 / J9 which in turn K3 / K6 relay to connect the 240 V ac to the coil. The VH relay is used to switch over between 24V and 15V supply for large and small focus respectively. It is energised through J5 optocoupler.

1.3.4 Filament Circuit

The interface for the filament is built in a series regulator form. The filament is driven for the required heating i.e. of the predetermined value of current through an arrangement of controller, driver circuit and final regulator circuit. Out of these three the controller circuit exists on the Master Card D915. The driver part J7 and the series regulator are formed on the Interface PCB D506.

1.3.5 Filament Supply and Heating

The DC supply of around 15 volts for small focus and 24 volts for large focus is obtained by SMPS 110 watts and 120 watts respectively. This is then passed through bridge rectifier to avoid wrong connections of positive and negative terminals of SMPS & passed by 2200µF capacitors. This capacitors help in reducing the heavy current spikes that might result if a single capacitor of a large value is used. The collector voltage to V20 transistor is given through NTC 2.5R to reduce inrush filament current. The firing Pulses for the driver optocoupler J7 are the Drive1 and Drive2 pulses added together. These pulses switch the driving transistor for the regulator 2N2222. In this manner the Power transistor 2N3055 V20 is operated in the switching mode to obtain the pulsating DC for the filament heating.

1.3.6 Filament Current Feed Back

The control circuit on the Master Card D915 receives the feedback voltage corresponding to the actual filament current in order to achieve the filament current regulation during standby and boosting states and Tube Current / mA regulation in case of exposure state. For this purpose one 0.1 Ω resistor is introduced in series with the filament. This gives current to voltage conversion.

1.3.7 Tube Current Feedback

Similar to Filament current feedback the tube current feedback is taken from the Single Tank is available at X2.4, X2.5. The combination of 100R resistances in parallel give the tube current ratio of 1 V = 20 mA.

1.3.8 Radiation triggering switches

The x-ray Radiation is generated using following switches.

1. Hand held Exposure switch – connected at X 27 connector on D506.
2. Hand held Fluoro switch – connected at X99 connector on D506.
3. Foot Switch – connected at HCL connector GA on D506

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1.4 Radiography Display & Memory Interface PCB D507

This PCB consists of

- ON / OFF switch.
- Parameter selection keys (kV & mAs)
- Service mode selection key
- Seven segment display for Radiography (kV and mAs values).
- Controls for memory selection for storage or retrieval of stored image and also transfer of the LIVE/LIH image to a corresponding memory location
- Control for the zoom in/zoom out of the image.
- Control keys for Live image rotation in clockwise and counter clockwise directions
- Control keys for the vertical movement of the motorised column
  The control signals generated in this PCB by activation of the relevant keys are send to the CCU / Master card D915 through the connecting cables.

1.4.1 Key Interface

No.	Identification	Description	Interface with
1		Unit OFF	D915
2		Unit On	D915
3	kV +	kV increment	D915
4	kV -	kV decrement	D915
5	mAs +	mAs increment	D915
6	mAs -	mAs decrement	D915
7	DL_Serv	Service mode select	D915
8	Memory select (M1 to M4)	Memeory location selection	CCU
9	Memory transfer key	Transfer of image to Memory	CCU
10	Up and Down key	Movement of motorised column	D508

1.4.2 Interface with Master controller PCB

The keyboard switches are connected to the Master controller PCB (Card) through FRC connector. The switch action will be conveyed to the Master Card by a switching Voltage signal. In normal condition when no key is pressed all the key lines will be maintained at LOW. This in turn should be reflected at the port of microcontroller as all high.

Whenever a key is depressed, it will be connected to the dc line and the corresponding line on the port of microcontroller goes low. Thus the corresponding data code appears on the Data bus of the Microcontroller which will be then read by the microcontroller through the software routine.

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1.4.3 Display Connections

The display consisting of 7 segment Display .The output of the display driver J24 of D915 is available in the X 50 connector. The output of the display driver is available in the below format.

1. mAs Unit
2. mAs tens
3. mAs Hundreds
4. kV Unit
5. kV Tens
6. kV Hundreds

The same data locations will be used for error code display also. In such case the Code will be displayed in the kV field and mAs hundredth place while the error code is displayed in the remaining mAs field.

1.5 Fluoroscopy Display & Generator Interface PCB D509

This PCB consists of

- Seven segment display for fluoroscopy kV and mA and cumulative fluoroscopy time values.
- Mode selection for standby/ fluoroscopy/radiography mode.
- Controls for Collimator open and close
- Controls for image reversal both horizontally and vertically.
- Control keys for Fluoroscopy mode and curve selection.
- Control keys for the vertical movement of the motorised column.

1.5.1 Interface with Master Controller PCB

The output of the display driver J40 on the D915 is available in the X40 connector. The display is available in the below format

1. Fluoroscopic time seconds1
2. Fluoroscopic time seconds2
3. Fluoroscopic time Minute
4. mA decimal Unit
5. mA unit
6. kV Unit
7. kV Tens
8. kV Hundreds

The other control switches are connected to the Master controller PCB D915 through X40 connector. The switch action will be conveyed to the Master Card by a switching Voltage signal in the analog port of the microcontroller.

The collimator open/close and the motor up down control are connected to PCB D508 through FRC connector.

1.6 Collimator Control and ADR Interface PCB D508

Controls for collimator opening and closing, up/down movement of the motorised column, Interface with the Camera control unit and selection of the ADR or manual mode for fluoroscopy.

This PCB should consist of

- Controls for iris collimator opening and closing.

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- Control interface for motor up/down movement.
- Control interface for the ADR mode of fluoroscopy.
- Control interface circuit for CCU from D507

The control signals for limiting the collimator opening are generated in this PCB based on the mode selection. These limit signals thus generated are sent to the collimator through the control to single tank cable.
The column lifting motor is bi-directional 230V AC induction motor. The 230V AC supply to the motor is switched through 24 V AC Contactor N1 and N2, which is further, controlled by the relay K1 and K2 on PCB D508. Interlocking is provided in relay K1 and K2 so that the both contactor can't be switched on at a time. +12V power supply from SMPS 2 is used for operating K1 and K2 relay. The switches responsible for UP/Down movement on control panel are S27 and S28 on PCB D507. Similarly switches S25 and S26 are for UP/Down movement on D509. Switches S25 & S26 and S27 & S28 are connected in parallel.
The up/down movement controls are generated in this PCB and the interface to the limit switches to limit the up and down extreme positions.
The signal available from the camera as an ABC (Automatic brightness control) is feed to the input of the buffer amplifier constructed by using IC TLO82.The ABC signal varies from -8 V to +8 V, this signal needs a voltage level conversion to be applied as a ADR (Automatic Dose Regulation) to the analogue port of microcontroller in PCB D915. The second stage is a summing amplifier used as a voltage level shifter by applying a constant negative voltage at the summing input. This voltage can be adjusted by the potentiometer. Refer Adjustment instructions in service instruction.
The output voltage is available as a ADR and varies as 0V to 5V DC, which is proportional signal to the brightness signal from Camera.
The control signals from the D507 fed to this PCB through X80, are inverted and applied at the S input of Quad RS Flip-Flop and reset signal for this is generated by a ORing other three signal. For example If S1 for Memory M1 is pressed then signal A is generated and B, C, D signal is ORed for the Flip-Flop 1. So we will get latched signal for M1 and reset signal for others. Similarly M2, M3, M4 signals are latched.
Zoom, Vertical Reversal and Horizontal Reversal signals are latched by using IC 4013. Output $\overline{Q}$ is applied at the Data pin, Inverted out put of switch (e.g. Zoom) is applied at clock input. So It holds the data and subsequently we gets the latched signal. These processed signals are fed to the CCU through the X90 cable.

1.7 Switch Mode Power Supply 40 watts (SMPS 1 & 2)

1.7.1 Specifications

- The Switch mode power supply, SMPS1 is used to supply + 5 Volts to the controller & associated circuitry ± 15 V to the driver circuits on PCB D915. ±15V supply is also used for ADR circuit on PCB D508.
- The Switch mode power supply, SMPS2 is used to supply circuitry on PCB D508.

The following are the specifications of the supplies.
+ 5 V at 3 Amps with Tolerance of 3%
+ 15 V at 0.3 Amps with Tolerance of 10 %
- 15 V at 0.2 Amps with Tolerance of 5 %

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This output is maintained for the following range of the input conditions.
110/190-240V ac at 50/60 Hz ± 2 Hz and an input current of 0.7 Amp rms.
All out puts are protected for short circuit conditions and a sharp repetitive sound is heard from the SMPS in the event of short circuit. The circuit behaves normally upon the removal of the short circuit.

1.8 S.M.P.S. (D982 of 120 watts)

1.8.1 Specifications

The Switch mode power supply D982 is used to supply + 24 Volts to the small focus Filament.
The following are the specifications of the supplies.
+ 24 V at 5 Amps with Tolerance of 3%
This output is maintained for the following range of the input conditions.
110/190-240V ac at 50/60 Hz ± 2 Hz and an input current of 0.7 Amp rms.
All outputs are protected for short circuit conditions. The circuit behaves normally upon the removal of the short circuit.

1.9 S.M.P.S. (D985 of 110 watts)

1.9.1 Specifications

The Switch mode power supply D985 is used to supply + 15 Volts to the large focus filament.
The following are the specifications of the supplies.
+ 15 V at 7.5 Amps with Tolerance of 2%
This output is maintained for the following range of the input conditions.
85 V ac to 264 V ac at 47 - 63 Hz and an input current of 1.8 Amp rms.
All outputs are protected for short circuit conditions. The circuit behaves normally upon the removal of the short circuit.

NOTE

For Servicing of Multimobil 5C with product status 03 refer to earlier version of service manual.

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